

# CAN LOW WATER/ROCK HYDROTHERMAL ALTERATION OF IMPACT MATERIALS EXPLAIN THE ROCK COMPONENT OF THE MARTIAN SOIL?

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**Introduction:** The martian regolith is a globally homogenized product of chemical and aeolian weathering processes. The soil [1] is thought to consist of a rock component, with lesser amounts of mobile elements (Ca, Na, and K) than a presumed protolith, and a “salt” or mobile element component enriched in sulfur and chlorine [2, 3]. In this study we consider the contributions of hydrothermal processes to the origin of the rock component of the martian soil.

McSween and Keil [4] investigated major element trajectories between Mars rocks and soils in an effort to distinguish between different processes that could contribute to the soil. They showed that the Mars soil is generally depleted in CaO, Na<sub>2</sub>O and K<sub>2</sub>O, but not FeO relative to the compositions of basaltic martian meteorites (Fig. 1). Comparisons of chemical trajectories for different processes led to the conclusion that the martian trends were most similar to trends due to palagonitization, the alteration of basaltic glass. Terrestrial ambient temperature weathering trajectories for basalts [5] are similar to the martian trends, but such environments are unlikely on Mars. The least successful models were the acid fog and hydrothermal models (Fig. 2) that show strong iron depletion in the altered material. The acid-fog model involves leaching of the mobile elements by acids produced from the deposition of S and Cl by volcanic aerosols [6]. A hydrothermal alteration model could involve volcanic or impact crater processes. The hydrothermal data used in the comparison by McSween and Keil was based on a study of ocean floor basalts [7], not the best analogue for martian processes. We have therefore examined both volcanic and impact hydrothermal systems to better understand the role of these processes on Mars.

**Volcanic hydrothermal processes:** A study by Aiuppa et al. [8] of hydrothermal fluids and associated lavas from Mt. Etna (Fig. 2) can be compared with similar data for ambient temperature alteration of basaltic lavas and tephra from Hawaii [5]. In contrast to the ocean floor basalts, the data for Etna, and the Hawaiian data are consistent with alteration trends similar to the ambient weathering trends (Fig. 1), including minimal depletions in iron. Some Etna fluids do have high Fe contents however.

**Impact hydrothermal systems:** We have obtained new microprobe data for alteration phases in samples from the Lonar and Mistastin impact craters, and used earlier data for the Ries crater (Fig. 3) for comparison with the Mars data. The 1.8 km diameter Lonar crater, India is emplaced in basalt and is a good

analogue for Martian craters [9]. The 28 km diameter, Mistastin crater contains an 80 m thick impact melt sheet [10, 11]. The 24 km diameter Ries crater contains hydrothermally altered impact breccias [12].

The compositions of Lonar bulk rock and associated alteration clays (mainly Fe-rich saponite) are plotted in Fig. 3, as well as data for similar phases from Mistastin and Ries. The arrows in Fig. 3 do not represent the alteration trends for the bulk rock, but connect the bulk material that has lost some Na, Ca, and K but retained a substantial amount of Fe, with the composition of the alteration clays. The impact crater materials, particularly those from Lonar, represent an incipient hydrothermal alteration under low water/rock ratio conditions [9]. Although Fe can be removed by hydrothermal processes, incipient alteration leads to the formation of Fe-rich clays and retention of Fe in the system. Materials that have experienced removal of Ca, Na, and K, but retained Fe-rich clays could produce some of the observed Martian trends.

**Conclusions:** Although high water/rock ratio hydrothermal processes, such as ocean floor alteration can remove iron, the data for Mt. Etna and Hawaii suggests this does not always happen. The impact crater data also suggest that iron is not removed during low water/rock alteration due to the retention of Fe in the alteration phases. Therefore, hydrothermally altered material eroded by aeolian processes, can yield alteration materials richer in Fe, and be consistent with the composition of the martian soil.

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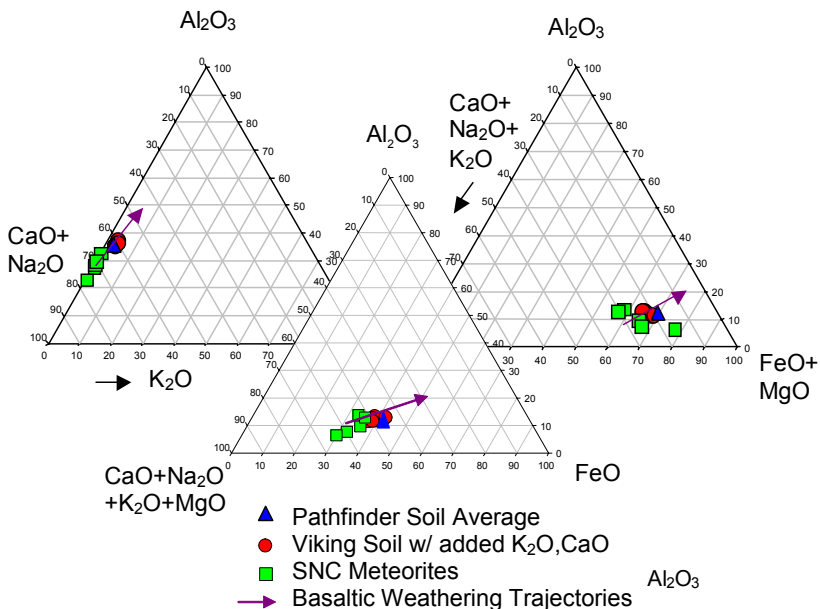


Fig. 1: The mars soil appears to be somewhat depleted in  $\text{CaO}$ ,  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$ , but somewhat enriched in  $\text{FeO}$ , relative to the rocks [Data from 4]. Weathering of basalts under ambient temperature conditions results in similar trends [5].

Fig. 2: Alteration trends are shown for terrestrial palagonitization [J-13, S&H-14], and ocean floor hydrothermal alteration [A&H-7]. Hydrothermal groundwater from Mt. Etna and the average Mt. Etna lava composition are also shown [8]. The loss of Fe during ocean floor alteration is not consistent with the martian trends.

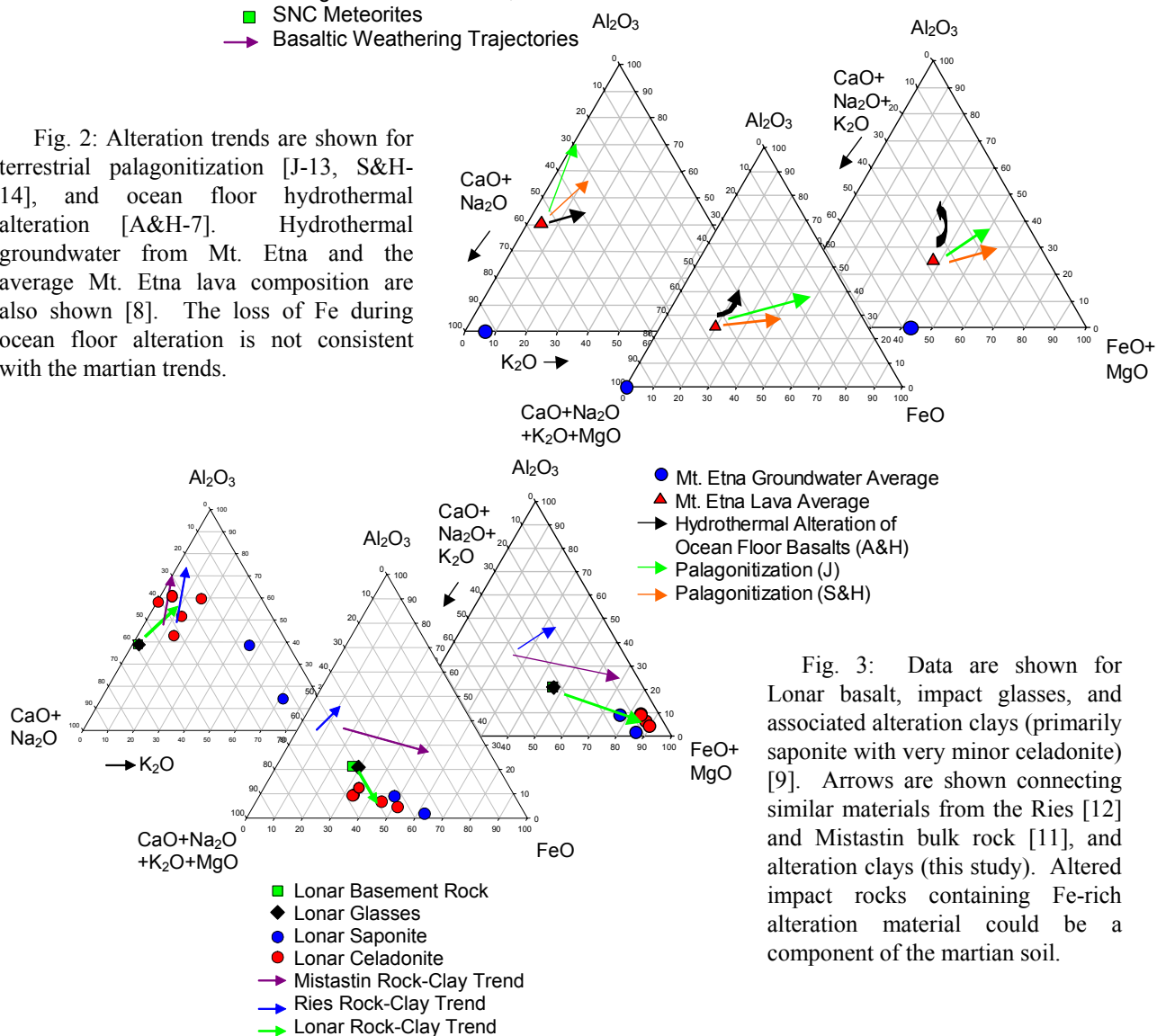


Fig. 3: Data are shown for Lobar basalt, impact glasses, and associated alteration clays (primarily saponite with very minor celadonite) [9]. Arrows are shown connecting similar materials from the Ries [12] and Mistastin bulk rock [11], and alteration clays (this study). Altered impact rocks containing Fe-rich alteration material could be a component of the martian soil.